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Minister of Fisheries

Homing Behaviour in Spawning Lake Trout

by

N. V. Martin

Ontario Department of Lands and Forests, Maple, Ontario

In 1954 three artificial lake trout spawning beds were established in an Algonquin Park, Ontario, lake (Martin, 1955). These were constructed at depths below the limits of late fall low water levels caused by drawdowns for hydro-electric power stations.

One of these areas, situated near a natural spawning ground which was not entirely exposed by low lake levels, was used by the lake trout while the other two were not.

It has been thought a homing tendency on the part of spawning lake trout might explain their deterrence to the use of these new areas. On the basis of tag recoveries in Lake Superior, Eschmeyer (1955) suggests lake trout in this lake may return to the same beds each year. Similarly tagging of Lake Superior lake trout spawning in the Dog and Montreal Rivers has shown their repeated return to the same river each year. (Loftus, 1957).

In order to acquire more definite information on this homing behaviour a study was made of lake trout movements at spawning time in Lake Louisa, a 1,480 acre lake in Algonquin Park, Ontario. This lake was chosen for the investigation as a good deal was already known about the reproduction of the lake trout in this lake from previous studies (Martin, 1957).

In 1951, 1956 and 1957 lake trout were captured on different spawning beds in Lake Louisa by small-mesh (2 and $2\frac{1}{2}$ inch) gillnets. These fish were tagged and the beds were subsequently kept under observation to determine the movements of these trout. Coloured (yellow, green, red, silver) plastic streamer tags and two points of insertion of these tags (anterior to dorsal fin and on caudal peduncle) were used to distinguish the trout of particular areas.

The tagged fish were identified by night observation on the spawning grounds, and occasionally by the use of gillnets when wind hampered visual observations. Tags were readily seen in the clear water of Lake Louisa in the two to five foot depths where most of the trout spawn.

Figure 1 shows the location of the major spawning areas where tagging was carried out (A, B, C, D, E) and other known spawning areas of lesser importance (G, H, I). The approximate distances in yards between major areas are as follows:

	A	B	C	D
B	180	–	–	–
C	1100	940	–	–
D	1400	1600	360	–
E	1700	1480	660	330

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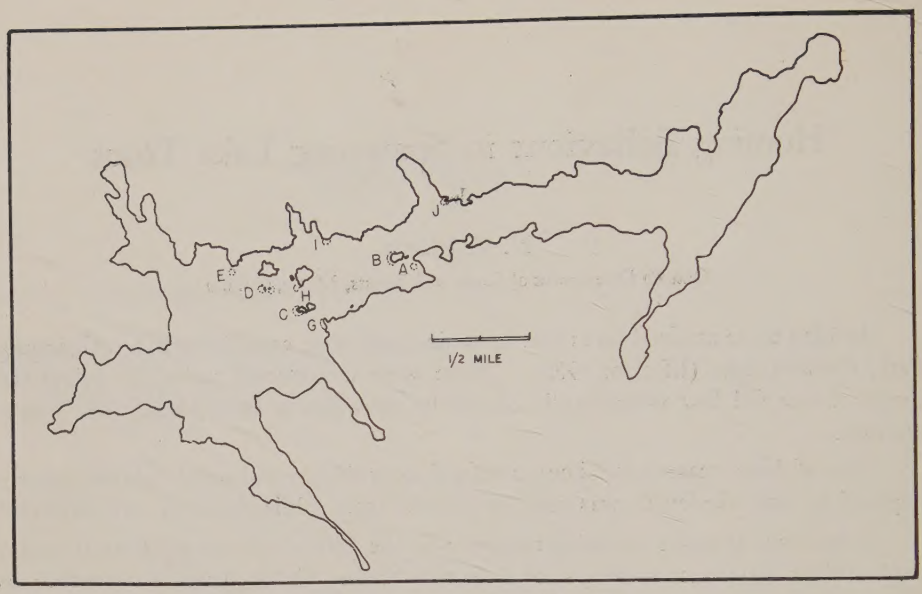

FIGURE 1.—*Location of known lake trout spawning beds, Lake Louisa, Ontario,*

A preliminary investigation of lake trout movements during spawning was made in 1951. On October 16 a total of 60 lake trout was tagged on four different beds (A, B, C, D). The following night 10 tagged fish were seen, all but two of which were on the same area in which they were tagged (see Table I).

In October of 1956 a total of 212 lake trout was tagged on five beds (A, B, C, D, E) on dates and in numbers as shown in Table 1. Of these, 173 were males, 31 females and eight were of undetermined sex.

On subsequent nights over a 19 day span (October 12-30), 44 tagged fish were seen, of which 16 were on the areas where they had been tagged. Of these 16 trout, 14 were on areas A and B, which are less than 200 yards apart, and there is considerable inter-mingling of trout between them. If these two are considered as one spawning ground there were then only three exceptions out of 54 tagged fish seen in 1951 and 1956 where trout were not observed on the same area as they were tagged. It is quite likely, of course, that the same fish may have been seen several times but this applies equally to fish returning to the same area and those that went to other areas, and therefore does not alter the general pattern of behaviour.

In 1957 checks were made on the fish tagged in 1956 to see if this apparent homing behaviour within a year held true between years. The results are shown in Table 1.

A total of 35 tagged fish were seen or caught in gill nets in the five nights of observations in 1957, all but one on the areas where they had been tagged (again considering areas A and B as one bed).

In 1958 and 1959 a further 11 tagged trout were observed, these fish again appearing on the same beds.

Therefore in the five years 1951, 1956, 1957, 1958 and 1959 all but five of 100 observed tagged fish have returned to the spawning area where they had been originally tagged.

Table I

Movement of lake trout between spawning beds on basis of observations of coloured tags, Lake Louisa 1951, 1956, 1957, 1958, 1959

Spawning Area	Date Tagged	Number Tagged	Dates of Observation	Number of Tags seen	Initial point of Tagging
	1951				
A	October 16	22	October 17	2	A
B	October 16	14	October 17	3	B
				1	A
C	October 16	18	October 17	3	C
				1	A
D	October 16	5	October 17	0	
	1956				
A	October 10, 11	55	October 12, 15, 19, 30	5	A
				1	B
B	October 11	37	October 12, 15, 19, 30	14	B
				13	A
C	October 5, 10, 24	61	October 15, 19, 30	7	C
				1	B
				1	E
D	October 24	32	October 24	0	
E	October 12	27	October 15, 19, 30	2	E
	1957				
A	—	—	October 14, 21, 22, 25, 28	11	A
B	—	—	October 14, 21, 22, 25, 28	8	B
				5	A
C	—	—	October 21, 22, 25, 28	7	C
D	—	—	October 22, 25, 28	2	D
E	—	—	October 22, 25, 28	1	E
F	—	—	October 25, 28	1	A
G	—	—	October 25	0	
	1958				
A	—	—	October 16. 20	2	B
B	—	—	October 16, 20	5	B
				1	A
C	—	—	October 16 20	0	
D	—	—	October 16, 20	0	
E	—	—	October 16, 20	1	E
	1959				
A	—	—	October 22	1	A
B	—	—	October 22	0	
C	—	—	October 22	1	C

On the basis of the above observations a homing behaviour is indicated in spawning lake trout. In order to initiate spawning on the second of the three artificial spawning beds in Shirley Lake, various measures were undertaken in 1956 and 1957 to attract the trout to this area. These included the penning of ripe fish over the beds, the transfer of rocks from used spawning areas, the blocking off of grounds that were being utilized, and the seeding of eyed eggs. This second spawning ground was used by the lake trout in the fall of 1958.

The third bed, which was kept as a control and where no attempts were made to attract the trout, was not used until 1959.

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In conclusion it would appear that in spite of a marked homing behaviour lake trout will spawn on new artificial beds. The utilization of these areas may be expedited by various attraction methods.

Acknowledgements

This study is part of the lake trout investigations being undertaken by the Division of Research of the Ontario Department of Lands and Forests in Algonquin Park, Ontario. The counsel and guidance of N. S. Baldwin in all phases of this work is gratefully acknowledged. The writer also wishes to thank H. G. Holmberg, R. J. Murdock, and R. P. Kuiack for their assistance in the field.

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Further Observations on the Survival of Yearling Lake Trout Planted in South Bay, Lake Huron

by

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The lake trout *Salvelinus namaycush* (Walbaum) has been studied since 1947 in South Bay in northern Lake Huron. Fry (1953) established that the South Bay lake trout formed essentially a closed population and described the passage of a strong 1944 year class through the fishery. He suggested that the sea lamprey was the factor responsible for the rapid and complete disappearance of what may well have been one of the last native lake trout populations in the main body of Lake Huron.

Since the disappearance of the last of the native trout in 1952, a population has been maintained in South Bay through the planting of fin-clipped yearling fish. The plantings were begun in 1949 and discontinued in 1955. The results of these plantings through 1956 were described by Fry and Budd (1958). Because larger numbers of trout were taken during the 1957 season, it seems advisable to summarize the data accumulated since the last mentioned paper. Any information concerning the survival of planted yearling lake trout is of immediate interest to the people and agencies concerned with the lake trout rehabilitation programme on the Great Lakes.

Catch and Population

The catch of lake trout taken from South Bay during the 1957 season was the largest since 1950, when native fish made up the entire catch. A total of 1,372 fish was taken in the net fishery and 12 were taken by anglers. Only 12 fish were not identified as fin-clipped, so it can be reasonably assumed the entire 1957 catch consisted of fish that had been planted in previous years. There has thus been no direct evidence of spawning in recent years; and further, the age distribution previously presented (Fry and Budd 1958) almost precludes the possibility of any mature fish having been present since the fall of 1951.

The net catches were made in two different types of gear: pound nets fished in May, June and early July, and gill nets fished later in the season. The pound nets took 578 fish and the gill nets 794. All fish taken in pound nets were tagged and released after scale samples had been secured and fork length measurements taken. All recaptures were recorded and released.

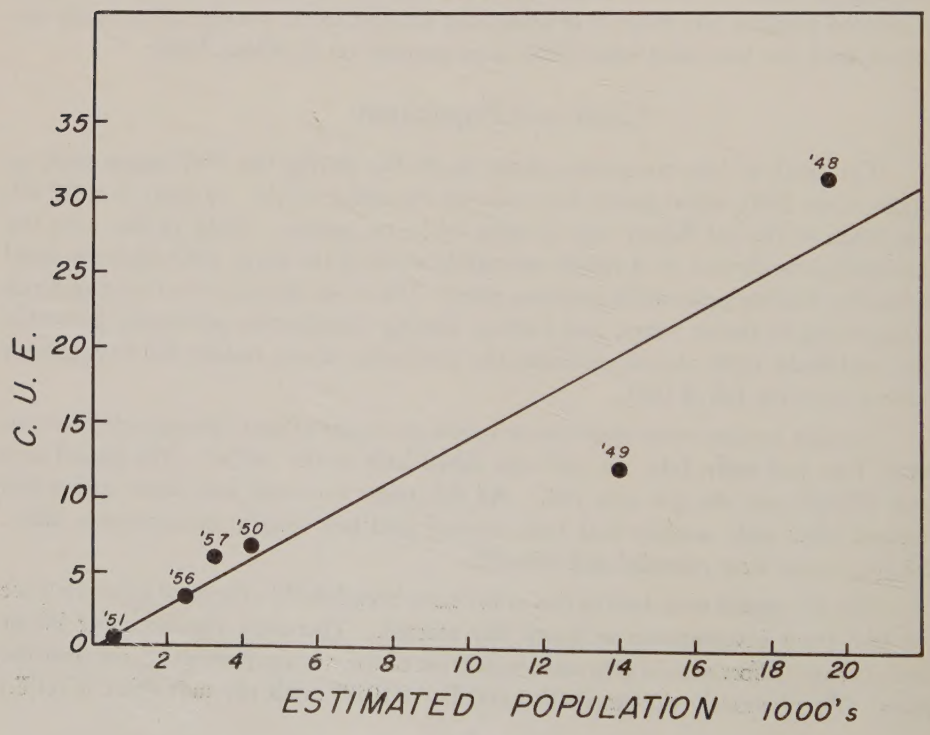
The five pound nets used in this study have been fished in the same locations since the lake trout investigation in South Bay started. Therefore, the catch per lift or catch per unit effort should give some indication of the relative population size over the years. As previously explained (Fry and Budd 1958) catch per unit effort (C.U.E.)

is defined as the average number of trout taken per pound net lift during the month of June. The 81 lifts of five pound nets made in June 1957 took 491 fish which amounts to an average of 6.1 per lift. The only years with higher catch per unit effort values were 1948, 1949 and 1950, when the values were 31.4, 11.8 and 6.9 respectively. The 1956 value was 3.2. In each of these years, except 1956 when figures are based on a Petersen estimate, enough fish were tagged to allow Schnabel type population estimates. It is of interest to compare the population estimates with the C.U.E. data. Fry (1953) presents population estimates for the years 1948, 1949 and 1950; Fry and Budd (1958) present the 1956 estimate. These estimates and the C.U.E. data are shown in Table I.

TABLE I

Year	C.U.E.	Population Estimate
1948	31.4	19,500
1949	11.8	14,000
1950	6.9	4,200
1951	0.6	600
1952	0.1	insufficient data for estimate
1953	1.4	insufficient data for estimate
1954	1.3	insufficient data for estimate
1955	0.3	insufficient data for estimate
1956	3.2	2,500
1957	6.1	3,200

FIGURE 1



A very close parallel can be drawn between the 1950 and 1957 figures. The 1950 estimate derived from 606 tagged fish and 50 recaptures was 4,160; the 1957 estimate from 530 tags and 42 recaptures was 3,200. The catch per unit effort values for the two years were 6.9 and 6.1 respectively.

Figure 1 shows the data contained in the table. Catch per unit effort is plotted against the population estimates. Estimates range between 500 and 19,500 and C.U.E. values between 0.6 and 31.4. Over this range there seems to be a good correlation between the estimated population and the C.U.E. For the years in which estimates are not shown, C.U.E. values ranged between 0.3 and 1.5, but recaptures were too few to allow meaningful population estimates. In any case, it can be seen that for the years 1952-1955 there were certainly less than 2,000 fish vulnerable to the pound net fishery.

Size, Age Composition and Mortality

Table II summarizes the age composition of the 1957 catch by the two types of gear. The complete absence of fish seven years of age and older, and the relatively few fish in the V and VI age groups is very striking. Estimates made in 1956 placed the number of age V fish at 500 (Fry and Budd 1958). When the estimate made in 1957 (Table I) is apportioned among the various age groups, an estimate of 40 is derived for the VI age group. This indicates a mortality in excess of 90 per cent for fish that were V in 1956 and would have been VI in 1957. Similarly, the mortality between age IV and age V was approximately 70 per cent. No estimate of the age III fish is available for 1956, but the age IV estimate made in 1957 does not indicate excessive mortality in this age group.

TABLE II

Age Distribution 1957—South Bay Lake Trout

Age	Pound Net	Gill Net	Total
III	310	598	908
IV	188	153	341
V	69	34	103
VI	5	3	8
No age	6	6	12
TOTAL	578	794	1372

(The Roman numerals indicate the number of completed annuli on the scale).

It is of interest to compare these figures with those from Fry (1953). Since Fry was dealing with essentially a single year class, that of 1944, his estimates in successive years gave total mortality from one age group to the next. Thus his estimate of 19,500 fish in 1948 and 14,000 in 1949 gave approximately 30 per cent mortality between age IV and age V. Using his population figures for 1949 and 1950 (Table I) mortality between age V and age VI is estimated at 70 per cent while the 1950-1951 pair of values, gave an estimated mortality of 86 per cent between the ages of VI and VII. These figures are comparable to those in the preceding paragraph obtained using 1956 and 1957 data broken down by age groups, except that between the years 1956 and 1957

the fish are one year younger when they sustain comparable mortality. Since data presented by Fry (1953), Fry and Budd (1958) suggests that lamprey predation is most severe on the larger fish, an increase in growth rate would account for the age difference.

Table III and Figure 2 summarize the growth data for the 1957 South Bay lake trout. Comparable data for the native fish for the years 1947-1950 (Fry 1953) are also shown. Since planting was discontinued in 1955 no age II fish were present in 1957. It can be seen from the table that fish of a given size were approximately one year younger in 1957 than during the period 1947-1950. If, as suggested later, the lamprey are selectively taking the largest, fastest growing individuals, these figures do not represent maximum potential growth.

TABLE III

Growth of South Bay Lake Trout, 1947-1950 and 1957

(Fork lengths inches and weights pounds—1947-50 data from Fry 1953)

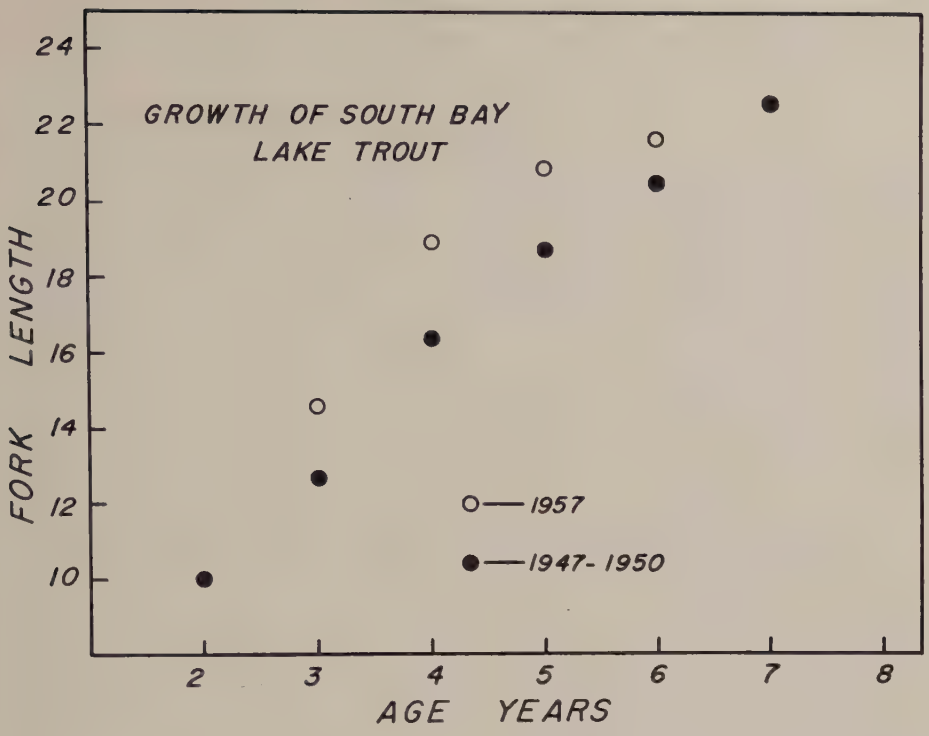
Year	Age Group					
	II	III	IV	V	VI	VII
1957 pound net—length	not present	14.9	19.0	20.9	21.4	0
1957 gill net—length	not present	14.4	19.1	20.9	22.1	0
weight	not present	1.2	3.0	4.1	5.0	0
1947-1950 mean values all gears—						
length	10.0	12.7	16.5	18.8	20.6	22.7
weight	0.4	0.7	2.1	2.8	3.8	6.7

Number of fish comprising means can be obtained from Table II.

Growth increments from tagged fish recaptured one year after tagging also showed a higher growth rate in 1957 than was shown in 1950. The 1949-1950 increment (Fry 1953) was 1.8 inches, while the 1956-1957 increment based on fifteen fish was 2.8 inches. The range was from a minimum of 1.2 inches to a maximum of 5.5 inches. This increase in growth rate is probably the result of an explosive increase in the alewife population that has taken place in Lake Huron over the past several years (Miller 1956). The 1951 South Bay catch of alewives consisted of a single individual, while the 1956 and 1957 catches were of the order of 20,000 pounds.

Since nearly all of the pound net fish were captured in May and June, and the gill net catch was spread over the period July 16-October 25, one could expect the gill net fish to reflect the growth of the 1957 season by an increase in average length. An examination of Table III shows that mean lengths, except in age groups VI where the number of fish is very small, are nearly identical for pound net and gill net fish. This relationship holds true for the age IV and age V fish, but the age III pound net fish are 0.5 inches larger than the gill net sample. The age IV and age V fish are completely vulnerable to both the pound and gill net fishery, while the age III fish are not; the smaller individuals of this group are not taken by the pound nets in proportion to their abundance in the population.

FIGURE 2



The explanation for the lack of seasonal growth can be obtained from the data on lamprey scars shown in Table IV. There is a marked increase in the percentage of lamprey scars with an increase in length. It is assumed that the largest, fastest growing individuals are the fish most likely to be attacked and killed by sea lampreys, and

TABLE IV

Incidence of Lamprey Scars on 1957 South Bay Lake Trout

	under 17.0	17.0-17.9	18.0-18.9	19.0-19.9	20.0-20.9	21.0-21.9	22.0 and up
Number of fish	863	98	89	106	77	76	42
Number scarred	23	18	22	53	49	48	22
Number of scars	25	20	25	72	95	76	29
Percentage scarred	3	18	25	50	63	63	52

	Age			
	III	IV	V	VI
Number of fish	908	341	103	8
Number scarred	38	130	68	5
Number of scars	45	192	95	10
Percentage scarred	4	38	66	63

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that these fish are selectively removed as the season progresses. For this reason, the average fork length does not show the expected increase.

Lamprey Scarring

All of the fish handled in the course of the lake trout study were examined for lamprey scars. Scars were classified as either fresh or healed, but for the sake of simplicity, only the figure for total scarring will be presented. Fish under 17 inches fork length show relatively few scars (Table IV). From that length upward, except in the 22-inch and up group, there is a progressive increase in the percentage bearing scars, and also in the number of fish bearing multiple scars. Two interpretations are possible: that single attacks are more likely to kill the smaller fish, and therefore small fish with scars are not often taken. It seems more probable from the data on survival previously presented that some difference in distribution relative to temperature and depth keeps the small trout and sea lampreys from the same area at the same time. It is known that the small trout are more numerous in the deeper waters of South Bay, while the larger fish are most often taken in shallower water just at the bottom of the thermocline.

Scarring percentages range from three per cent on fish under 17 inches to 63 per cent on fish in the 20-22 inches class. With lamprey populations continuing at the present level, we can expect the last of the planted lake trout to disappear from South Bay during the 1960 season. Since female lake trout in South Bay do not mature until age VII it is highly unlikely that any egg deposition will have resulted from the 78,900 marked yearling fish which were planted over the years 1949-1955. Without lamprey predation, plantings of this magnitude would certainly have established a self-sustaining population with a normal age distribution.

Survival in the Absence of Lamprey Predation

Some data are available which allow one to compare the survival of hatchery-reared yearling lake trout to age VI in the presence and in the absence of sea lamprey predation. In October of 1952 fin-clipped yearling lake trout from the same parents and otherwise similarly treated were planted both in South Bay and Lake Manitou.

Lake Manitou, an adjacent lake on Manitoulin Island, is similar to South Bay in size and depth, and in the type of fish population it supports. Both bodies of water have smallmouth bass, pike, perch, smelt, ling, lake trout and whitefish populations. The major difference lies in the absence of a sea lamprey population in Lake Manitou.

An intermittent creel census has been conducted on Lake Manitou since 1947 to compare angling there with that in South Bay. In 1957 this creel census was intensified and an attempt made to examine as much of the lake trout catch as possible in order to record recaptures of the marked fish.

The South Bay plant consisted of 23,100 fish, while 10,100 were planted in Lake Manitou. The total 1957 South Bay catch of age VI fish (no native fish of this age were taken) was eight (Table 2), five were taken in pound nets, three in gill nets and none in the limited angling fishery that took 12 fish. Survival of the 23,100 fish to age VI is estimated to be 40 or approximately 0.2 per cent. By contrast, 16 of a total of 68 lake trout examined in the Lake Manitou creel census were identified as

from the 10,100 planted in that lake in 1952. It is estimated that at least a further 100 of the same planting were handled during the course of spawn taking operations on Lake Manitou in October of 1957. Since the lake trout population of Lake Manitou is known to be large, such recovery would indicate a much higher percentage survival to age VI.

Angling

The yearling fish planted in South Bay have provided very little angling. This is in contrast to the native population described by Fry (1953) where some 3,500 fish from an estimated population of approximately 20,000 were taken by anglers. In 1950, when estimates based on pound netting were very similar to the 1957 estimates, anglers took at least 418 fish, while in 1957 only 12 were recorded. With the decline in the trout population from the 1948-1949 level, there has been a decided lack of interest in angling for lake trout, and many of the guide boats that formerly spent considerable time trolling for trout are now either no longer operating or are used entirely for fishing bass and pike. Summer weather, with fresh afternoon breezes on most days, tends to discourage most owners of small outboard boats from fishing the open waters where the lake trout are commonly taken at that season. It is unlikely that any interest in the lake trout angling fishery will be shown until a population of trout similar to that present in 1949 is again established. It would seem that this must await lamprey control.

Conclusion

The data presented suggest that if the sea lamprey is controlled, there will be no difficulty in re-establishing a lake trout population in South Bay. Survival of planted yearlings to age IV is good, but the fish are completely eliminated by the sea lamprey before any of the females reach sexual maturity at age VII. To gain time, plantings should begin two or three years before complete control is in effect, and plantings of from 10,000 to 20,000 yearling of as large size as possible should be made for five or six years. At the end of this period, it could be expected that a population with a normal age distribution would be present. This population would then become self-sustaining.

There is reason to believe that these same conclusions would be valid for Lake Huron proper, the North Channel and Georgian Bay. Every effort should be made to gather data on former lake trout spawning grounds and on the former distribution of small lake trout in these waters, so that plantings may be made in the areas where optimum survival could be expected.

Acknowledgements

The co-operation of the entire staff of the South Bay Fisheries Research Station made this study possible. Especial thanks are due to J. B. Smith who read the scales and to W. I. Chapman under whose able direction the fishing was carried out.

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Variation in Vertebral Count in F_2 Hybrids of *Salvelinus Fontinalis x S. Namaycush*

by

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Introduction

The "splake", as the F_1 hybrid between *Salvelinus fontinalis* and *S. namaycush* has come to be known in Ontario, has been considered as a replacement for the Great Lakes lake trout, which is suffering greatly from the ravages of the parasitic sea lamprey. Lake trout seem particularly vulnerable to the attacks of the lamprey and it is felt that one of the chief reasons for this vulnerability is the length of their reproductive cycle (five to seven years to first spawning). Fry (1957, pers. comm.) has suggested a long-term programme of selective breeding to obtain a fish combining the three-year reproductive cycle of the speckled trout with the propensity of the lake trout for the benthic environment. As a preliminary to this programme, the segregation of parental characters in the second filial generation was investigated by the examination of a single meristic character, the vertebral number, in a sample of 200 specimens.

Materials and Methods

The fish used were hatched from eggs obtained from the first stock of splake produced in Ontario, at the Dorion Hatchery of the Department of Lands and Forests in 1951, of which some matured in 1954. Two thousand of the second generation hybrids produced from these survived to 1957 at the Hill's Lake hatchery.

At Hill's Lake the hybrids were kept in a large concrete raceway and raised on a poultry mash, liver and cod liver oil formula. Probably because of the extremely low water temperatures at this northern hatchery, growth was quite slow. The sample of these two year-olds of which the vertebrae were counted averaged only 5.1 inches (fork length), and ranged from $3\frac{1}{4}$ to $9\frac{1}{2}$ inches. First generation hybrids have commonly reached four inches in length by the end of the first year (Baldwin, 1956).

Considerable variation was noted in the appearance of the fish. First generation splake which have been planted in different lakes often differ somewhat in coloration and markings, but, in general, deviation from the characteristic intergrade form is usually slight. With the F_2 hybrids, on the other hand, much variation was noted. Caudal fin shapes, for example, ranged all the way from the square tail characteristic of the speckled trout to the typically forked tail of the lake trout. There was no apparent relation between size and the appearance of these characters. That is, large hybrids resembling speckled trout seemed to occur as frequently as those resembling the lake trout and *vice versa*. The accompanying photograph (Plate 1) illustrates the variation in form and markings.

PLATE I.—*Photograph of F_2 splake showing variation in size and markings.*

The vertebral counts were made from X-rays of live fish anaesthetized with MS222 (tricaine methane sulfonate). The fish were selected by choosing every eighth fish as the raceway was emptied of hybrids. However the number of fish had been underestimated by 661, and these remained after the selection of the 200. It was assumed that these specimens would not differ in size from the rest of the stock, so they were simply measured and released with the rest. This assumption unfortunately proved wrong. The mean length of the surplus was 4.7 inches, compared with 5.1 inches for the sample selected to be X-rayed. There is a highly significant difference (0.01 level of confidence) between these means. While the selection was in progress, it was found more convenient to dipnet the fish at the upstream end of the pen in which they had been concentrated, and apparently the residual fish were the smaller weaker specimens which did not fight the raceway current as strongly. There was no relation however, between size and vertebral count in the sample examined.

The facilities of the Kirkland Lake General Hospital were made available on March 10. The hospital's radiologist, Dr. Burrows, and his technician took the X-ray photographs during two hours of the afternoon. They had previously experimented with dead fish supplied by the Department of Lands and Forests to develop the technique so no time was lost on this account. The fish were kept outside the hospital in a tank aboard a hatchery truck and carried in lots of twenty to the radiology room, as needed. Once X-rayed they were immediately returned to the truck and placed in a separate tank.

For the X-ray photography, photographic plates in their packages were placed under the tube, marked with small metal numerals and covered with dampened newspaper. The fish were anaesthetized, measured to the fork of the tail (to the next lower one-eighth inch), and placed on the plate. They were arranged in a staggered fashion, ten to the plate, with the left side up and heads to the left. This arrangement allowed the measurements for individual fish to be related to their photographs.

The exposure was set at six milliamp.-seconds at 60 kilovolts but varied somewhat with the mean size of lots of fish. "Ilfex" film was used and it was developed at 68°F. for $4\frac{1}{2}$ minutes.

Vertebral counts were made from the X-rays over a light table. Two counts were made for each fish: the vertebrae were counted twice from the occipital region back to the tail, then from the tail forward. The first anterior vertebra was discerned as that carrying the first neural process posterior to the occiput. The third centrum carried the first pair of ribs. Owing to the fineness of the bones in these small fish many of the individual elements of the caudal skeleton were obscure. The last caudal vertebra could not be distinguished in the X-ray plates from the "caudal bony plate" (Vladykov, 1954) dorsad and the bases of the 4th, 5th, 6th, and 7th hypural bones posteriad. However, as can be seen in Plate II, this complex of bones appeared as a conspicuous dense area and was counted as the last caudal vertebra in each case.

To ensure the accuracy of the vertebral counts a larger ($15\frac{1}{2}$ inches fork length) dead lake trout was subsequently X-rayed and dissected. It was found that the above description of the caudal skeleton, as observed on the X-ray plates, conformed exactly with that of Vladykov (*loc. cit.*) for salmonoid fish, making the X-ray vertebral counts exactly comparable with the counts made from dissections by that author.

PLATE II.—*X-ray photograph of a lake trout. Scale is in centimeters.*

Since it is hoped in future to select those hybrids best adapted for a deep-water existence, it was of interest to determine whether or not the size of the swimbladder is meristically determined. To this end the total visible length of each swimbladder (which appeared as a dark area) was measured to the nearest one-eighth inch.

Results

Vertebral counts for the hybrids ranged from 56 to 66, averaging 61.4 with a standard deviation of ± 1.7. These data are shown in Fig. 1 as a frequency polygon. Counts on 13 speckled and 23 lake trout from Vladykov (*loc. cit.*) are similarly plotted for comparison. Since meristic characters are influenced by thermal experience during embryonic development (Tåning, 1952 and others), caution must be exercised in comparing the curves. It is obvious, however, that the hybrids exhibited a great deal of variation in vertebral number, and the range for this sample exceeds the total range for the other two curves. Each of the speckled and lake trout samples had a coefficient of variation of 1.9 per cent. The coefficient for the hybrid sample was 2.8 per cent.

The three measurements made on the hybrids were compared by means of a partial correlation analysis on data from 100 of the fish X-rayed. The results of this analysis are shown in Table 1.

TABLE 1

Partial Correlation Analysis. A—fork length; B—vertebral number; C—swimbladder length

$r_{AB} = 0.02448$	$r_{BC} = 0.0650$	$r_{AC} = 0.8733$
$r_{AB.C} = -0.06641$	$r_{BC.A} = 0.08958$	$r_{AC.B} = 0.8733$
	$R_{B.AC} = 0.09282$	

The only correlation coefficient (r) which is significant is that for the regression between fork length and swimbladder size, and the vertebral number has no relation to either of these variables. The multiple correlation coefficient (R) for the relation between vertebral number and the other two variables is far below the level of significance (.2 at the .05 level). This analysis demonstrates that the size of the swimbladder is related only to the size of the fish. The size of the swimbladder is probably not a good criterion of a fish's ability to retain its swimbladder gas under pressure. It also appears that the length bias in the sample had no effect on the distribution of vertebral counts.

Discussion

The wide range of vertebral number in this sample and perhaps also the range in size, appear to be good evidence of normal pairing of chromosomes and subsequent segregation in the F_2 generation. Speckled trout and lake trout both have 84 chromosomes in somatic tissue (Buss and Wright, 1956) and this presumably accounts for the viability which apparently reaches 75 per cent (Stenton, 1952) when lake trout eggs are fertilized with speckled trout milt. If the two parent chars had been genetically distinct for a period long enough for major changes in the chromosomes to have occurred, normal synapsis would have been impossible and the F_2 hybrids could only have been produced through polyploidy or from gametes carrying a preponderance of chromosomes from one or the other of the parental species. Had meiosis in the F_1 generation been abnormal, one could have expected low fertility and off-spring either distinctive with respect to heritable meristic characters or closely resembling one of the parent

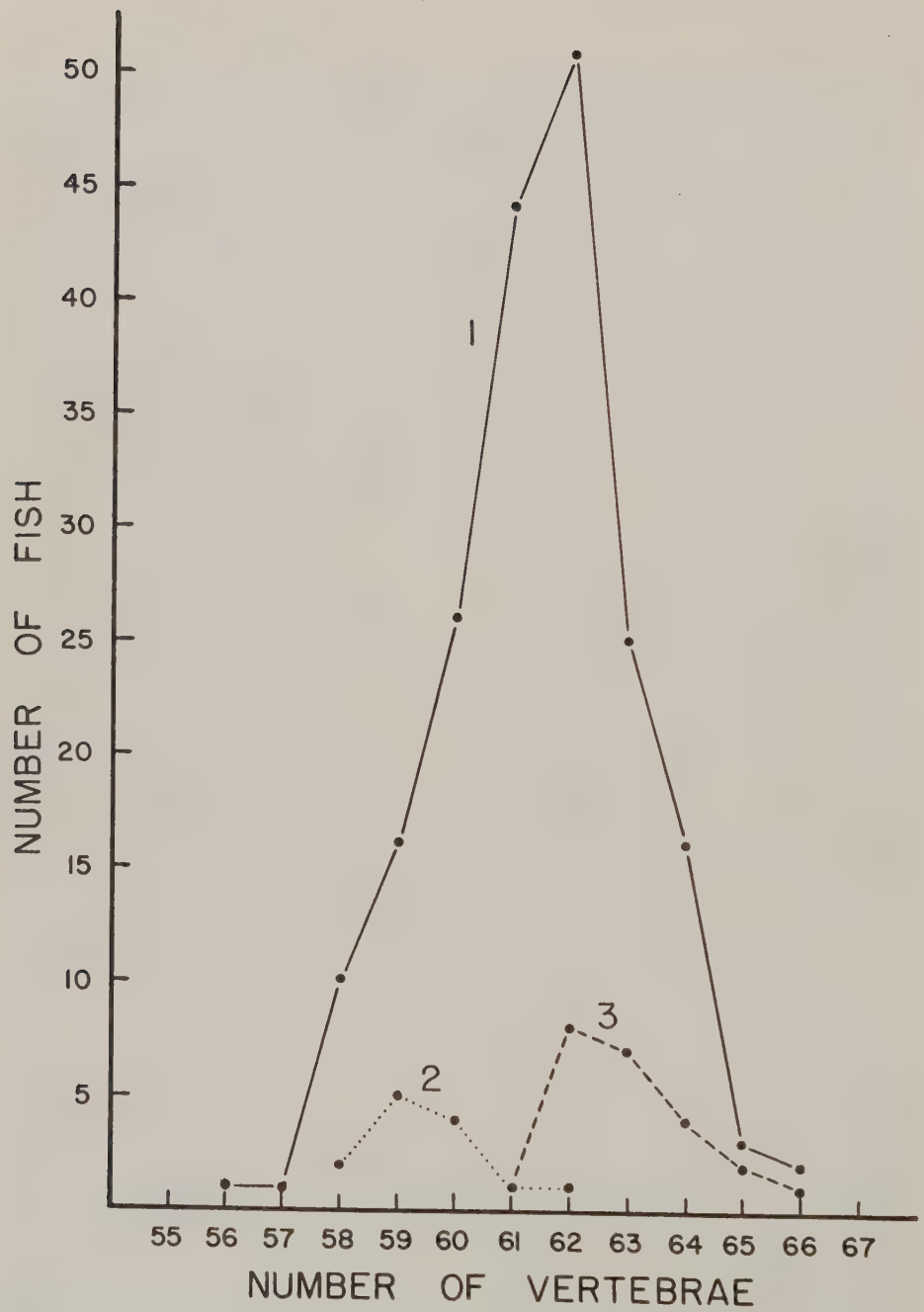

FIGURE 1.—*Frequency distribution for vertebral counts on samples of F_2 hybrids (No. 1, 200 spec.), S. fontinalis (No. 2, 13 spec.) and S. namaycush (No. 3, 23 spec.). Data for numbers 2 and 3 from Vladykov, (1954).*

species. Since segregation took place for vertebral number, it is likely safe to assume that this would be true for all genetically determined characteristics. We can therefore tentatively conclude that the splake is a true hybrid, from recently evolved parent species, and selection for desirable characters to produce a new form is theoretically possible.

It further seems evident that in lakes which provide satisfactory habitat for one or the other of the parent species, planted splake will only retain their identity for a few generations.

Acknowledgements

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Comparative Tagging Returns Employing Three Different Anaesthetics

by

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In the spring of 1955 a population study of the yellow pickerel, *Stizostedion v. vitreum* (Mitchell), was initiated in the Nipigon River, Lake Superior, and adjoining tributaries. A total of 2,200 yellow pickerel had affixed to them a red plastic streamer tag as outlined by Joeris (1953). Five hundred and forty-nine of these pickerel are not considered in this study as they were caught first in small meshed gill nets. It was readily observed that even with the precautions taken the mortality among these fish (as evidenced by subsequent tag returns), was noticeably higher than those fish initially captured by other methods, regardless of the anaesthetic employed.

Procedure

Consequently, the returns from a total of 1,651 tagged yellow pickerel were considered in this study. The majority of these fish were captured by dip net in the lower Nipigon River, six miles upstream from Nipigon Bay of Lake Superior. The remainder were captured by seine or by angling at the same site or at other sites in the same water system. Most of the pickerel were tagged at night immediately prior to spawning, by a crew of three working with headlamps. All fish were handled in the same manner; measured first, sexed when possible, tagged and returned to the water immediately.

The project was started using commercial ether, ethyl oxide, as an anaesthetic, as urethane, ethyl carbamate, could not be obtained locally at that time. After urethane became available, it was chiefly employed as the anaesthetic and ether reverted to only in case of an ermergency shortage of urethane. Urethane was discontinued in 1956 when its carcinogenic qualities were published (Wood, 1956). In its place M.S. 222, tricaine methanesulfonate was used for the remainder of the tagging operations.

Comparison of Anaesthetics

In every case the anaesthetic was not used in predetermined amounts, but was first tested on a few of the pickerel until a satisfactory concentration was obtained. The liquid ether was found to dissolve rapidly in the water but its high volatility made frequent replenishment necessary, and fumes from the solution were extremely unpleasant to those working in the vicinity. On at least two occasions the author became partially narcotized from prolonged exposure to these fumes. The pickerel took longer to become anaesthetized with ether than when urethane or M.S. 222 were employed. It was found that even after anaesthesia had taken place with ether the

fish would still produce spasms when handled, making tagging difficult. When fish were completely overcome by ether, either by prolonged exposure or an overdose, subsequent revival rarely occurred. Fish in this condition were placed in a back eddy in the river and observed during the remainder of the tagging operation for that night. Only rarely did a fish right itself and swim away.

Urethane was found to be highly satisfactory for this project. It anaesthetized the fish more rapidly than ether and emitted no objectionable fumes to the operator. It was found difficult to dissolve in cold water (34°F. to 38°F.) in which most of the tagging operations took place. Anaesthesia was realized more rapidly than in the case of ether but a longer period of time was needed to completely anaesthetize the fish. Most of the latter fish again showed signs of life when returned to fresh water. Urethane required replenishment only when the mucus covering from the fish and other debris became excessive in the solution. Fish which were anaesthetized in urethane were easy to handle, spasms occurring less frequently than when ether was employed.

M.S. 222, although at first resorted to as an emergency measure, has been found more satisfactory in all respects than either ether or urethane except in the rapidity of dissolution. In this respect it dissolves more rapidly in cold water than does the urethane crystals, but not as rapidly as the liquid ether solution. No objectionable odour is apparent, and the fish appear to become anaesthetized more rapidly than with either ether or urethane. Violent spasms rarely occur thereby greatly facilitating the tagging operation. Fish which were overcome by M.S. 222 can usually be completely revived in a short while with apparently no ill effects. Most of the fish could be left in the solution longer than with urethane or ether. M.S. 222 solutions, like urethane solutions, required changing only when overladen with slime and debris.

TABLE I

Percentage tag returns following use of three anaesthetics in tagging procedure

Anaesthetic Employed	Number of Fish Tagged	Number Tags Returned After 2 Years	Percentage Return of Tags
Ether	178	24	13.5
Urethane	969	175	18.1
M.S. 222	504	160	31.7

Tagging Returns

Tag returns of pickerel anaesthetized with ether, urethane and M.S. 222 vary greatly (Table I). As the majority of these fish were tagged and released under similar conditions most variables will be eliminated. All fish were tagged by the author, two assistants helping in capturing the fish and recording data. It must be remembered that this tagging project was primarily designed to be a portion of an extensive population study and was not set up to test the relative merits of the three anaesthetics. Hence constant concentration levels were not used as the molality of the solution was in general increased (by adding more of the solute) with a decrease in water temperature. Had the experiment been designed to test ether, urethane and M.S. 222 and compare the

same, consistent concentrations of each should have been employed, and three equal groups of pickerel tagged each night employing each of the three anaesthetics separately.

The rate of tag return will also vary according to the varying rates of natural mortality over the tagging and recapture period, combined with variability of the effectiveness of harvesting agencies (in this case commercial fishermen and anglers). These variables would have been greatly reduced had a controlled experiment as outlined above been employed. Lastly, the tagged fish must be considered to be randomly distributed within the total population. Enough information is not available at present to establish this condition.

M.S. 222 exhibited a far greater return of tagged pickerel than did either ether or urethane (Table I). Of 504 fish released, 31.7 per cent were subsequently returned during the following two year period. Urethane showed a return of only 18.1 per cent and ether 13.5 per cent from a release of 969 and 178 tags respectively. The lower rate of return for fish anaesthetized with ether and urethane can possibly be attributed to an assumed higher mortality shortly after tagging. This mortality could be caused from a toxic or other deleterious effect of the anaesthetic on the fish, or external or internal injuries caused by the operator by squeezing the fish when spasms occurred. Hence possible injury effected in this manner would be directly proportional to the number and vigorousness of the spasms produced. It would follow then that internal injury caused by pressure on the fish would be greatest when ether was employed as the anaesthetic and least when M.S. 222 was used. Removal of mucus from the fish probably occurred most often with ether and least with M.S. 222 and would also be directly proportional to the spasms produced and hence the relative facility with which the fish could be handled.

Summary

From the available data tag returns from a total of 1,651 yellow pickerel tagged were greatest when M.S. 222 was employed as an anaesthetic. Much lower rates of return were experienced with fish anaesthetized in urethane or ether. The increased rate of tag return resulting when M.S. 222 was employed was possibly due to a lesser toxic or other deleterious effect, or to a more complete narcosis of the fish and thereby greatly facilitated the handling and increased the rate of tagging when fewer spasms were produced.

Acknowledgements

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Mr. G. C. Armstrong critically read the original manuscript.

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A Possible Source of Error in Assessing the Survival of Pacific Salmon Eggs by Redd Sampling

by

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Introduction

The survival of salmon eggs during incubation in the gravel has been commonly assessed by redd sampling at some period after deposition. This sampling method has been described by Hobbs (1937) and involves excavating the nest or redd and collecting the eggs and/or alevins in a net as they are swept downstream by the current. The ratio of the number alive to the number dead is taken to represent the survival in the area examined.

Some doubt has arisen as to the validity of survival values obtained by this method. There is some evidence that dead eggs may be lost to the investigator through various agencies either before or at the time of sampling. Carl (1939) planted a known number of coho eggs (*Oncorhynchus kisutch*) in gravel and found upon later examination that all the eggs he originally planted could not be accounted for. Shaw and Maga (1943) and Briggs (1953) reported similar results also on coho. W. M. Cameron of the Fisheries Research Board, Biological Station at Nanaimo, B.C. investigated the possibility of dead eggs disintegrating during the redd sampling procedures. He found a significant loss of coho eggs occurred when dead eggs were planted in gravel and then immediately dug up.

Sockeye (*Oncorhynchus nerka*) redd sampling was carried out by the author at Scully Creek, Lakelse Lake, B.C. In many instances, particles of dead eggs were observed in the gravel and on the collecting net while redds were being dug, indicating that disintegration and loss of eggs had occurred. Also a smaller number of eggs were recovered per sample in the spring than in the fall, although the effort expended per sample was considered about the same in each season. A review of Cameron's data suggests a similar occurrence in pink salmon redds (*Oncorhynchus gorbuscha*). He examined over 60 redds at various times after deposition. The average number of eggs recovered per sample decreased as the time spent in the gravel increased. Redds sampled within 50 days of deposition averaged nearly 1,000 eggs. This figure dropped to less than 700 after 150 days. Assuming that the effort expended on each sample remained the same throughout the sampling period, it would appear that a considerable loss of eggs occurred.

Method

In order to determine the conditions under which the loss of eggs may occur and to obtain some idea of the extent of such loss, sockeye eggs were placed in artificial redds and their fate recorded.

Artificially fertilised eggs were placed in 15 screened boxes containing gravel of various sizes. The boxes, 12″ x 8″ x 10″ deep, were made of plywood. The ends were covered with common metal fly screening to permit water circulation through the gravel. Five boxes of small, medium and large gravel were used. The small gravel consisted of particles less than $\frac{1}{4}$″ in diameter; the medium was greater than $\frac{1}{4}$″ but less than 1″; the large gravel was between 1″ and 2″ in diameter.

Fifty cc. of eggs were placed in each box in the following manner. A layer of gravel, approximately 3″ deep was placed in the bottom of each box. The box was then placed under water and the measured quantity of eggs placed in a small pocket made in the gravel. The eggs were gently covered with gravel to avoid crushing and the box filled to within 1″ of the top. The boxes were placed on the bed of a small stream, in moderate current and under at least 6″ of water.

Fertilization and planting was carried out on August 27, 1953. Nine, 50 cc. samples of eggs were counted to estimate the number placed in each box. This was found to be 258 (standard deviation 13.5). All boxes were examined seven months later, just prior to the time that fry emergence usually takes place. Care was taken that all eggs present in the boxes were recovered. Notes were kept of the condition of the gravel in each box, the condition and stage of development of the eggs and the presence or absence of other organisms.

Results

It was found when the boxes were examined that almost total mortality had occurred by the time the mid-eyed stage was reached. One individual had survived to alevinage but had died prior to the examination. This mortality was attributed to excessive silting of the gravel as a result of freshets in the previous fall and also to the nature of the containers which no doubt restricted water circulation in the gravel. Eyed and un-eyed eggs in various stages of decomposition were recovered from each box. In addition, many minute particles of dead eggs were observed. The small size of these particles prevented even a rough estimate of the number of whole eggs they represented. Decomposition was more advanced and egg particles were more numerous in the boxes containing medium and large gravel. The eggs in the small gravel were relatively firm and had retained much of their original shape and colour.

The number of whole eggs recovered is given in Table I. In all but three boxes the number recovered was significantly less than the number originally planted. The most probable number of eggs planted in the 14 boxes examined (one of the 15 originally seeded was lost) was 14 x 258 or 3612 eggs. The total recovered was 2810 or 78 per cent of the probable number planted. A loss of about 22 per cent, therefore, took place during the period in the gravel.

As suggested above, the loss of eggs was greater in the medium and large gravel than in the small. The number of whole eggs recovered from the four boxes containing small gravel ranged from 212 to 263 compared to 105 to 237 in the medium and 160 to 209 in the large. In Table I the apparent and actual survival of the eggs to the eyed stage is given. The apparent survival was calculated from the number of eggs recovered in each box while the actual survival was calculated from the number of eggs planted in each box. These values are compared graphically in Figure 1. The medium and

TABLE I

Contents of egg boxes examined April 5 to 14, 1954
Average of 258 eggs (standard deviation 13.5) planted per box

	No whole eggs recovered	No. dead			% survival to eyed stage	
		Pre-eyed	*Eyed*	*Alevins*	Apparent	Actual
Small gravel—						
Box No. 1....	212	183	29	—	13.6	11.2
2....	256	256	0	—	0	0
3....	226	226	0	—	0	0
4....	263	263	0	—	0	0
					Mean 3.4	2.8
Medium gravel—						
Box No. 1....	237	106	131	—	55.3	50.8
2....	188	97	91	—	48.4	35.3
3....	105	101	4	—	3.8	1.6
4....	203	109	93	1	46.3	36.4
5....	186	163	23	—	12.4	8.9
					Mean 33.2	26.6
Large gravel						
Box No. 1....	209	57	152	—	72.7	58.9
2....	160	72	88	—	55.0	34.1
3....	178	100	78	—	43.8	30.2
4....	177	86	91	—	51.4	35.3
5....	209	46	163	—	78.0	63.2
					Mean 60.2	44.3

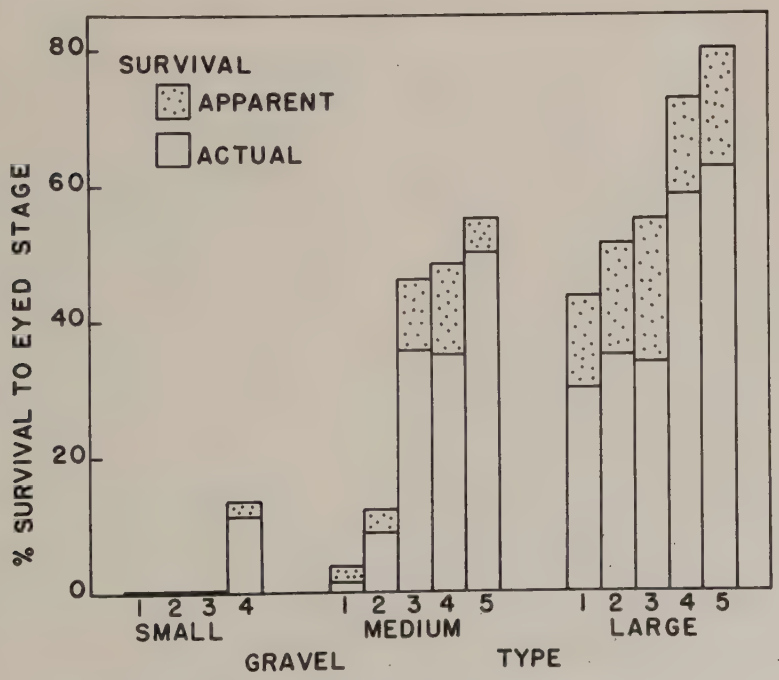

FIGURE 1.—*The apparent and actual survival of sockeye salmon eggs to the eyed stage.*

large gravel was most conducive to survival and also to the disintegration and loss of eggs. The apparent survival was, therefore, correspondingly higher than the actual in these two gravel types than in the small gravel.

A number of aquatic forms were found to be closely associated with the egg clusters. Insect larvae and nymphs were frequently encountered and occasionally a few oligochaetes and lamprey larvae were found. The abundance of these organisms varied from box to box and varied in each type of gravel. Extensive fungus growths and numerous insects were found in the medium and large gravel while the small gravel was relatively "sterile" and contained very few of these forms. The larvae or "blood worms" of the Tendipididae were found in large numbers both on and inside the eggs. Entry into the eggs was made through a small sharp edged hole in the shell. It was presumed that the bloodworms were subsisting on the dead materials inside. Stonefly nymphs, (*Chloroperlidae*), and cranefly larvae, (*Tipulidae*), were also present but in smaller numbers than the bloodworms. Whether or not they subsisted on the egg materials was not certain, but the fact that they were often found in the midst of the egg clusters, suggests they did. Eggs in all stages of fungusing were evident. Fungus had attacked the eggs singly or in clusters wherein it was often difficult to separate out the individual eggs.

Discussion and Summary

The evidence indicates that a considerable loss of dead eggs may occur during the incubation period in the gravel. The agencies responsible for this destruction include fungus, midge and cranefly larvae, and stonefly nymphs. Although there was evidence to show that dead eggs were consumed, it could not be determined if living eggs were attacked.

The extent of the loss which occurred was related to the type of gravel in which the eggs were planted. This in turn apparently determined the abundance of organisms which acted as agents of destruction. Large gravel was more suitable for the survival and development of the sockeye eggs, and also presumably more suitable for the existence of fungus and insect forms. Loss or destruction of eggs in the larger gravel was, therefore, greater than in the other types. Total non-recovery in all three types was estimated to be in the order of 22 per cent of the number planted. Although the conditions under which the eggs existed were artificial, there is reason to believe that in comparable conditions of restricted water flow and silting, such losses would occur naturally. Survival values determined from redd sampling may, therefore, be erroneously high, particularly in large gravel where disintegration of dead eggs most frequently occurs.

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A Modified Roller Press for Scale Impressions

by

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The use of scale impressions in determining the age of fish has steadily increased since its early development (Nesbit, 1934). Several of the methods employed require the use of hydraulic presses (Greenbank and O'Donnell, 1950), pneumatic presses (Butler and Smith, 1953), or roller presses (Arnold, 1951), (Smith, 1954).

The roller press, preferred by many workers, has one disadvantage. In order to obtain the correct pressure the space between rollers has to be set accurately. If the cellulose acetate slides and scales are uniformly thick, adjustments of the machine are infrequent and of minor concern. When slides vary in thickness adjustments are frequent and a relatively high percentage of the scales require re-rolling. This difficulty can be overcome by placing the upper roll of a jeweller's rolling press under air pressure held constant at any desired pressure up to 200 p.s.i. Uniformly good impressions are obtained despite differences in slide and scale thickness and at a relatively high speed.

A jeweller's rolling press was modified as shown in the accompanying photographs. The entire manual roll pressure adjusting mechanism and hand operating parts were discarded. In place of these, the unit was motorized and the desired roll pressure was obtained by means of a pneumatic diaphragm.

This diaphragm can be connected to any convenient source of compressed air. In this case, compressed air cylinders are used. The required roll pressure, to suit the particular species of fish scale under examination, is adjusted and held constant by means of a pressure reducing valve. The diaphragm air hose, compressed air cylinders and reducing valve are clearly shown in the photographs.

To equalize the roll pressure, the diaphragm push rod acts on a yoke, which in turn presses on each end bearing of the upper roll. These bearings are free to move up and down in vertical guides. Adjusting nuts on this yoke serve to set the initial gap between the rolls. This gap is essential for ease of inserting the slides. Small irregularities in the slide thickness are automatically compensated for, with negligible change in the roll pressure, by the up and down movement of the yoke and diaphragm, as the slides pass between the rolls. Part of this yoke can be seen at "A" in Figure 1.

For speed and ease of operation, this device is driven by a $\frac{1}{4}$ h.p. motor, belt-connected to a 50 to 1 worm reductor, which in turn is directly coupled to the driving roll. A maximum rotation speed of the roll of about 35 r.p.m. is desirable. Excessive speed tends to flip the scales from the slide as they enter the machine.

Figures 1 and 2 show the essential features which have been incorporated, both for ease of operation and for the safety of the operator.

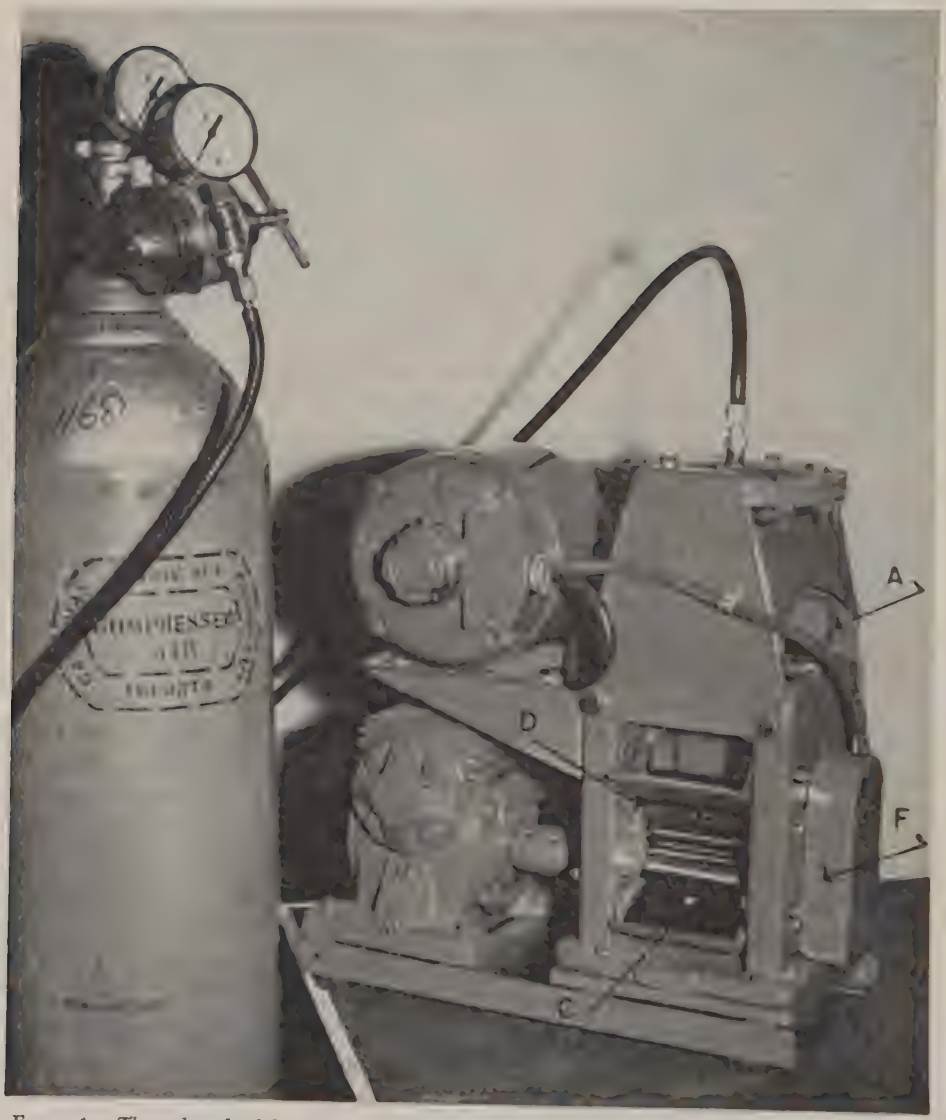

FIGURE 1. *The outlet side of the rolls. "C" is the slide chute, "D" shows plexiglass wipers to remove any scales that stick to the rolls, and "F" is the roll gear drive guard.*

FIGURE 2. *The inlet side of the rolls. "B" is the combined slide platform and finger guard, and "E" is a guard for the drive belt between the motor and the worm reductor.*

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